CHAPTER 1 Review

REFLECTING ON CHAPTER 1

- Dynamics relates the motion of objects to the forces acting on them.
- Inertia is the tendency of objects to resist changes in motion.
- In an inertial frame of reference, Newton's laws of motion describe motion correctly. Inertial frames of reference might be stationary or moving at constant velocity.
- In non-inertial frames of reference, Newton's laws of motion do not accurately describe motion. Accelerating frames of reference are non-inertial.
- Fictitious forces are needed to explain motion in non-inertial frames of reference. If the same motion is observed from an inertial frame of reference, the motion can be explained without the use of fictitious forces.
- Inertial mass is equivalent to gravitational mass.
- Frictional forces are described by the equation $F_f = \mu F_N$, where μ is the coefficient of friction between two surfaces and F_N is the normal force pressing the surfaces together. The coefficient of kinetic friction (μ_k) applies when the object is moving. The coefficient of static friction (μ_s) applies when the object is motionless.
- The weight of an object is the gravitational force on it ($F_g = mg$).
- Free fall is vertical motion that is affected by gravitational forces only. In free fall, all objects accelerate at the same rate.
- Terminal velocity is the maximum downward speed reached by a falling object when the force of air friction becomes equal to the force of gravity.
- Air resistance depends on the surface area, shape, and speed of an object relative to the air around it.

Knowledge/Understanding

1. Identify and provide examples of what physicists consider to be the two "natural" types of motion.
2. What is the term used to describe the tendency for objects to have differing amounts of "persistence" in maintaining their natural motion?
3. What concept is used to quantify the inertia of an object?
4. Distinguish between, and provide examples of, inertial and non-inertial frames of reference.
5. Imagine that you are looking sideways out of a car that is stopped at a stoplight. The light turns green and your driver accelerates until the car is travelling with uniform motion at the speed limit.
   - **(a)** Sketch a velocity-time graph of your motion, illustrating the time intervals during which you were stopped, accelerating, and travelling with a constant velocity.
   - **(b)** Identify the time interval(s) during which you were observing objects at the side of the road from an inertial frame of reference or from a non-inertial frame of reference.
   - **(c)** Use this example to explain why Newton's first and second laws do not accurately predict the motion of the objects you are observing at the side of the road while you are accelerating.
6. You know that if you drop two balls from rest from the top of a building, they will accelerate uniformly and strike the ground at the same time (ignoring air resistance). Consider these variations.
   - **(a)** Suppose you drop a ball from rest from the top of a building and it strikes the ground with a final velocity v_f. At the same time that the first ball is dropped, your friend launches a second ball from the ground with a velocity v_f, the same velocity with which the first ball strikes the ground. Will the second ball reach the top of the building at

the same time that the first ball strikes the ground? Explain where the balls cross paths, at half the height of the building, above the halfway point or below the halfway point. Ignore air resistance.

(b) You launch a ball from the edge of the top of a building with an initial velocity of 25 m/s [upward]. The ball rises to a certain height and then falls down and strikes the ground next to the building. Your friend on the ground measures the velocity with which the ball strikes the ground. Next, you launch a second ball from the edge of the building with a velocity of 25 m/s [downward]. Ignoring air resistance, will the second ball strike the ground with greater, smaller, or the same velocity as the first ball?

Hint: what is the velocity of the first ball when it is at the height of the top of the building (after falling from its maximum height) and on its way down?

7. You are having a debate with your lab partner about the correct solution to a physics problem. He says that the normal force acting on an object moving along a surface is *always* equal and opposite to the force of gravity. You disagree with this definition.

(a) Provide the proper definition for the normal force acting on an object.

(b) Describe, with the aid of free-body diagrams, three situations in which the normal force acting on an object cannot be determined using your lab partner's definition.

(c) Describe, with the aid of a free-body diagram, a situation in which your lab partner's definition could apply.

Inquiry

8. You are given two bowling balls. One is pure wood, while the other has an iron core. Your task is to verify Newton's laws. Accordingly, you set up an inclined plane in such a way that you can let the balls roll down the plane and along the floor.

(a) Design an experiment to determine which ball has more inertia.

(b) Sketch a velocity-time graph to illustrate your predictions of the motion of each ball.

(c) Explain how Newton's first law affects the motion of the ball during each phase of its motion. Explain your reasoning.

(d) Draw a free-body diagram for each ball as it descends the ramp. Write equations to predict the acceleration of each. Provide an analysis of the equations to show that each ball's acceleration down the ramp should be the same.

(e) The analysis in **(d)** seems to defy Newton's first law. Initially, you might predict that the ball with more inertia would have a different acceleration. Provide an explanation, based on Newton's laws, of why the ball with more inertia does not experience a greater acceleration.

9. Recall the apparatus set-up you used for Investigation 1-A to explore inertial mass. In this case, you are given a dynamics cart that has a mass of 500 g and you use a falling mass of 200 g.

(a) Assume that the coefficient of friction between the cart and the ramp is 0.12. Calculate theoretical predictions for the acceleration of the system when incremental masses of 100 g, 200 g, 300 g, 400 g, and 500 g are added to the cart.

(b) Plot an acceleration-versus-incremental-mass graph for your theoretical values.

(c) Does the line on this graph pass through the origin? Explain your reasoning.

(d) What acceleration is indicated at the point where the line on the graph crosses the *y*-axis?

(e) Describe two different modifications you could make to this set-up so that the cart would have zero acceleration.

Communication

10. Draw a free-body diagram of a diver being lowered into the water from a hovering helicopter to make a sea rescue. His downward speed is decreasing. Label all forces and show them with correct scale lengths.

11. Use free-body diagrams to show that the tension in the rope is the same for both of the following situations.
    (a) Two horses are pulling in opposite directions on the same rope, with equal and opposite forces of 800 N.
    (b) One horse is pulling on a rope, which is tied to a tree, with a force of 800 N.

12. A toy rocket is shot straight into the air and reaches a height of 162 m. It begins its descent in free fall for 2 s before its parachute opens. The rocket then quickly reaches terminal velocity.
    (a) Sketch a velocity-time graph for the descent.
    (b) Draw a free-body diagram for each of the three passes of the descent: the free fall, the parachute opening and slowing the descent, and terminal velocity

13. A large crate sits on the floor of an elevator. The force of static friction keeps the crate from moving. However, the magnitude of this force changes when the elevator **(a)** is stationary, **(b)** accelerates downward and **(c)** accelerates upward. Explain how the three forces should be ranked from weakest to strongest.

14. Two blocks, of mass M and mass m, are in contact on a horizontal frictionless table (with the block of mass M on the left and the block of mass m on the right). A force F_1 is applied to the block of mass M and the two blocks accelerate together to the right.
    (a) Draw a free-body diagram for each block.
    (b) Suppose the larger block M exerts a force F_2 on the smaller mass m. By Newton's third law, the smaller block m exerts a force F_2 on the larger block M. Argue whether $F_1 = F_2$ or not. Justify your reasoning.
    (c) Derive an expression for the acceleration of the system.
    (d) Derive an expression for the magnitude of the force F_2 that the larger block exerts on the smaller block.
    (e) Choose different values of M and m (e.g. M = 2m, M = 5m, including the case M = m) and compare the magnitudes of F_1 and F_2.
    (f) Comment on the above results.

Making Connections

15. Car tires are designed to optimize the amount of friction between the tire surface and the road. If there is too little friction, the car will be hard to control. Too much friction will negatively affect the car's performance and fuel efficiency.
    (a) List the different types of road conditions under which cars are operated. Research the different types of tread designs that have been developed to respond to these conditions. Explain how the different designs are intended to increase or decrease the coefficient of friction between a car's tires and the road.
    (b) Compare the positive and negative factors of using "all-season" tires rather than changing car tires to suit the season (e.g., changing to special winter tires). Do a cost analysis of the two systems and recommend your choice for the climatic conditions in your own community.

Problems for Understanding

16. Suppose a marble is rolling with a velocity of 3.0 m/s[N] and no horizontal force is acting on it. What will be its velocity at 10.0 s?

17. What is the mass of a sack of potatoes that weighs 110 N (1.1×10^2 N)?

18. A physics teacher is in an elevator moving upward at a velocity of 3.5 m/s when he drops his watch. What are the initial velocity and acceleration of the watch in a frame that is attached to **(a)** the elevator and **(b)** the building?

19. **(a)** What is the acceleration of a 68.0 kg crate that is pushed across the floor by a 425 N force, if the coefficient of kinetic friction between the box and floor is 0.500?
    (b) What force would be required to push the crate across the floor with constant velocity?

20. A red ball that weighs 24.5 N and a blue ball that weighs 39.2 N are connected by a piece of elastic of negligible mass. The balls are pulled apart, stretching the elastic. If the balls are released at exactly the same time, the initial acceleration of the red ball is 1.8 m/s^2 eastward. What is the initial acceleration of the blue ball?

21. If a 0.24 kg ball is accelerated at 5.0 m/s^2, what is the magnitude of the force acting on it?

22. A 10.0 kg brick is pulled from rest along a horizontal bench by a constant force of 4.0 N. It is observed to move a distance of 2.0 m in 8.0 s.
    (a) What is the acceleration of the brick?
    (b) What is the ratio of the applied force to the mass?
    (c) Explain why your two answers above do not agree. Use numerical calculations to support your explanation.

23. A football is thrown deep into the end zone for a touchdown. If the ball was in the air for 2.1 s and air friction is neglected, to what vertical height must it have risen?

24. A 2200 kg car is travelling at 45 km/h when its brakes are applied and it skids to a stop. If the coefficient of friction between the road and the tires is 0.70, how far does the car go before stopping?

25. A 55.0 kg woman jumps to the floor from a height of 1.5 m.
    (a) What is her velocity at the instant before her feet touch the floor?
    (b) If her body comes to rest during a time interval of 8.00×10^{-3} s, what is the force of the floor on her feet?

26. You are pushing horizontally on a 3.0 kg block of wood, pressing it against a wall. If the coefficient of static friction between the block and the wall is 0.60, how much force must you exert on the block to prevent it from sliding down?

27. The maximum acceleration of a truck is 2.6 m/s^2. If the truck tows another truck with a mass the same as its own, what is its maximum acceleration?

28. A force F produces an acceleration a when applied to a certain body. If the mass of the body is doubled and the force is increased fivefold, what will be the effect on the following?
    (a) the acceleration of the body
    (b) the distance travelled by the body in a given time

29. A 45.0 kg box is pulled with a force of 205 N by a rope held at an angle of 46.5° to the horizontal. The velocity of the box increases from 1.00 m/s to 1.50 m/s in 2.50 s. Calculate
    (a) the net force acting horizontally on the box.
    (b) the frictional force acting on the box.
    (c) the horizontal component of the applied force.
    (d) the coefficient of kinetic friction between the box and the floor.

30. A Fletcher's trolley apparatus consists of a 4.0 kg cart and a 2.0 kg mass attached by a string that runs over a pulley. Find the acceleration of the trolley and the tension in the string when the suspended mass is released.

31. You are a passenger on an airplane and you decide to measure its acceleration as it travels down the runway before taking off. You take out a yo-yo and notice that when you suspend it, it makes an angle of 25° with the vertical. Assume the plane's mass is 4.0×10^3 kg.
    (a) What is the acceleration of the airplane?
    (b) If the yo-yo mass is 65 g, what is the tension in the string?